Reference: 1

Author	Fernando J. Serra
Title	Advanced Search Techniques for Alignment and Registration
From	Intelligent Vision '99, June 28-29, 1999

Advanced Search Techniques for Alignment and Registration

Fernando J. Serra
Imaging Technology Incorporated
55 Middlesex Turnpike
Bedford, Massachusetts 01730

ABSTRACT

For over a decade, machine vision/automation engineers have relied on normalized grayscale correlation to locate patterns in precision alignment and registration applications. Despite years of commercial success, experienced proponents of this mainstream vision tool are the first to admit that there are certain limitations and caveats associated with its use, especially when the appearance of objects are subject to change due to normal process variations.

Where most of today's traditional pattern locating software tools fall short is in their finicky training processes and in their inability to adapt to normal process variations encountered on the manufacturing floor. These process variations produce such visible phenomenon as non-linear contrast/lighting gradients, contrast reversal, missing or occluded features, blur, artifacts, shadows or reflections, noise, angular or scale changes. Traditional normalized grayscale correlation search tools simply cannot cope with such variations in object appearance.

For OEMs, system integrators and end-users of machine vision requiring highly accurate and robust pattern finding tools capable of precisely locating patterns despite normal process variations, Imaging Technology Incorporated recently introduced a new search technique which overcomes today's pattern matching challenges. The new developments in search algorithms provide extremely accurate and robust pattern locating tool featuring a Training Wizard -- a time-saving utility that takes the guesswork and uncertainty out of the pattern training process. With state-of-the-art geometrical based search engine, the new search tools enables manufacturers of vision-automated equipment to build more robust machines that will automatically adapt to changes in object appearance due to normal process variations.

Keywords: pattern recognition, alignment, adaptive grayscale search, machine vision, robust, automation, process variation

INTRODUCTION

Machine vision has evolved to become a mainstream automation tool enabling computers to replace human vision in high-speed and high-precision manufacturing applications. This important automation tool is now being used to ensure quality in manufacturing of everything from diapers to the chips that power today's most powerful computers.

Some industries have pushed the envelope more than others. In general, those requiring greater levels of precision and robustness have demanded that machine vision tools become more adaptive to in-process variations and provide reliable results despite changes in appearance that can occur during the manufacturing process.

Machine Vision in Industry

The specific industry segments that have pushed the envelope in machine vision are semiconductor and electronics manufacturing. In these segments, machine vision tools are used to precisely guide robotic handling, assembly, and

inspection processes. Some examples of semiconductor manufacturing equipment requiring precision automated alignment include:

- Wafer sorters/handlers/robots
- Ion implanters
- Wafer steppers
- Wafer probers
- Wafer dicers
- Die pick & place
- Die bonders
- Wire bonders
- Dispensers
- Screen printers

What each of these machines has in common is the need to precisely align or register objects such as semiconductor wafers or die so that operations such as lithography, cutting, placing, and/or bonding can be performed to extremely tight tolerances. The machine vision tool that has emerged as the single most important implement for performing precision alignment and registration is the grayscale pattern recognition search or pattern locating tool.

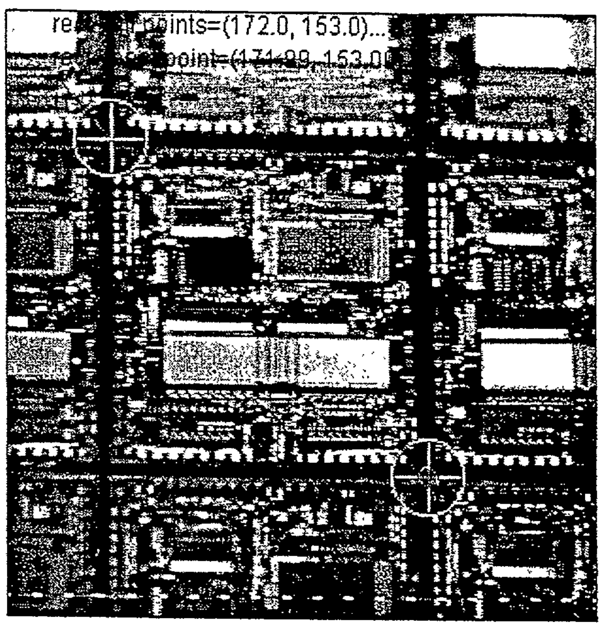

Figure 1. Grayscale pattern recognition used to precisely locate position and orientation of die on a semiconductor wafer for the purpose of controlling a wafer dicer machine as it prepares to cut individual die from the wafer.

The most significant challenge for machine vision in these automated machine applications is maintaining the ability to locate reference patterns despite changes in material appearance. Some examples of changes in visual appearance that can manifest due to normal process variation include:

- Non-linear contrast variation or reversal
- Partial obliteration from debris
- Blur from focus or depth-of-field changes
- Object scale or size deformations
- Angle of orientation

In order to be completely effective in communicating accurate positional data to the alignment and registration process, pattern recognition tools must be able to adapt to the phenomenon listed above.

APPLICATION OVERVIEW

Fine Alignment of Patterned Wafers

Fine alignment of patterned wafers is most commonly the initial process carried out by automated semiconductor and electronics manufacturing machines mentioned in section 1.1 herein. The machine vision tasks are typically as follows:

1. *Determine position of the wafer in the field-of-field (FOV) to within 1 micron in X and Y.*
2. *Determine orientation of the wafer in the field-of-field (FOV) to within 0.1 degree theta.*

The first step in setting up any pattern recognition process is to train the system on the pattern of interest. Unfortunately, the shortcoming of normalized grayscale correlation tools found in most commercial packages today is that once they're trained on a particular pattern, they cannot cope with changes in appearance to the pattern at run-time. Therein lies the limitation of most of today's commercial pattern recognition software packages.

In patterned wafer alignment applications, machine vision challenges are commonly as follows:

Vision Challenge 1: Pattern recognition must handle contrast reversal and non-linear intensity gradients.

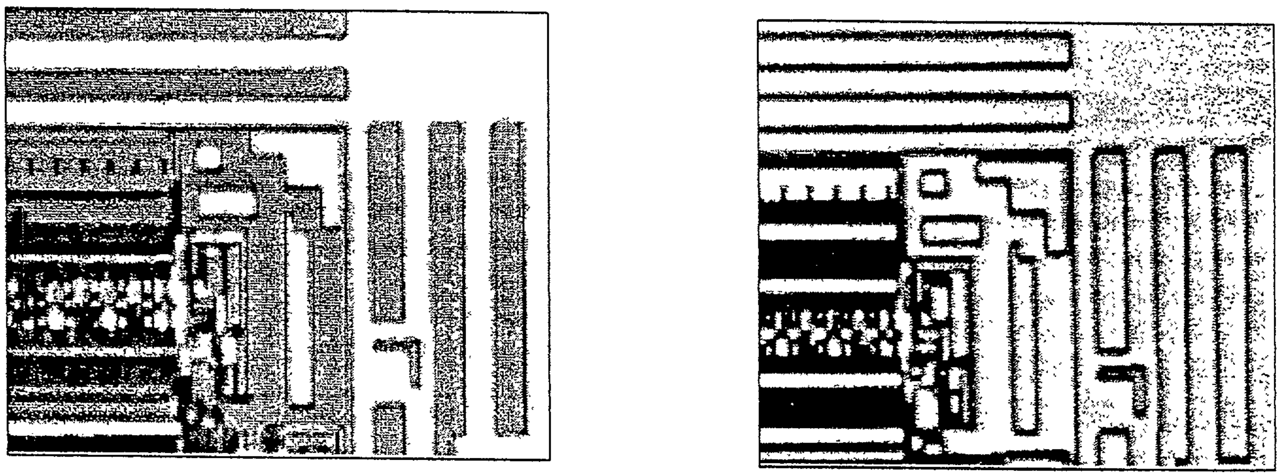

Figure 2. Field-of-view of a semiconductor wafer exhibiting contrast reversal due to Chemical Metal Planarization (CMP) process.

Vision Challenge 2: Pattern recognition must handle angle of orientation uncertainties.

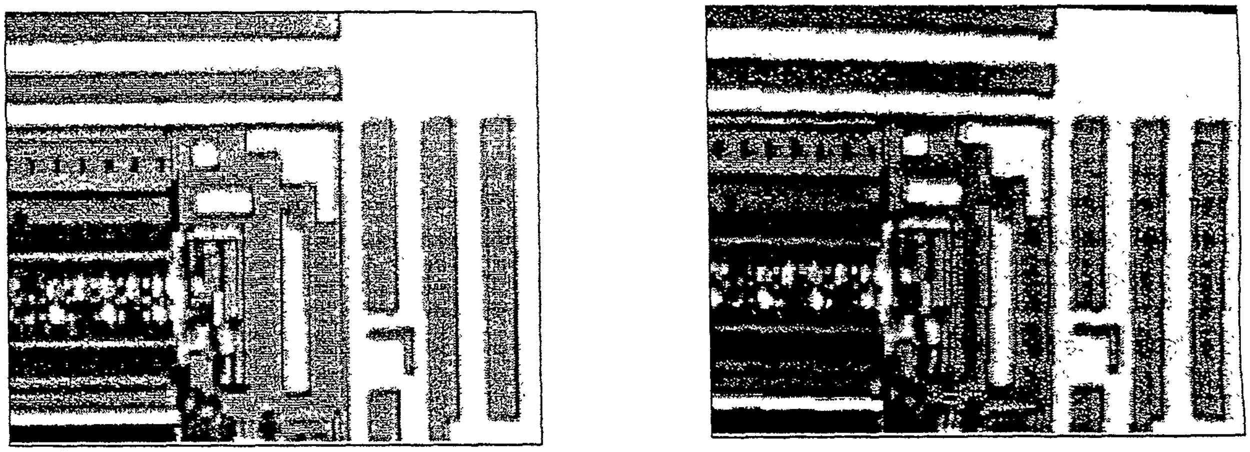

Figure 3. Field-of-view of a semiconductor wafer exhibiting changes in angle of orientation due to mechanical positioning uncertainty.

Vision Challenge 3: Pattern recognition must handle blur due to changes in depth-of-field.

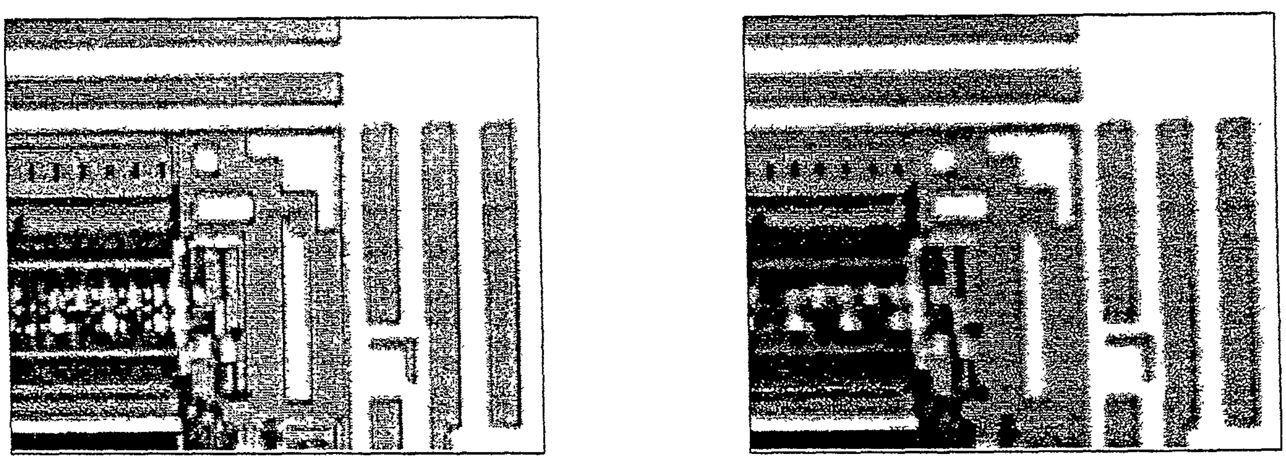

Figure 4. Field-of-view of a semiconductor wafer exhibiting blur due to changes in focus or depth-of-field.

Vision Challenge 4: Pattern recognition must handle changes in scale due to process variation or perspective changes.

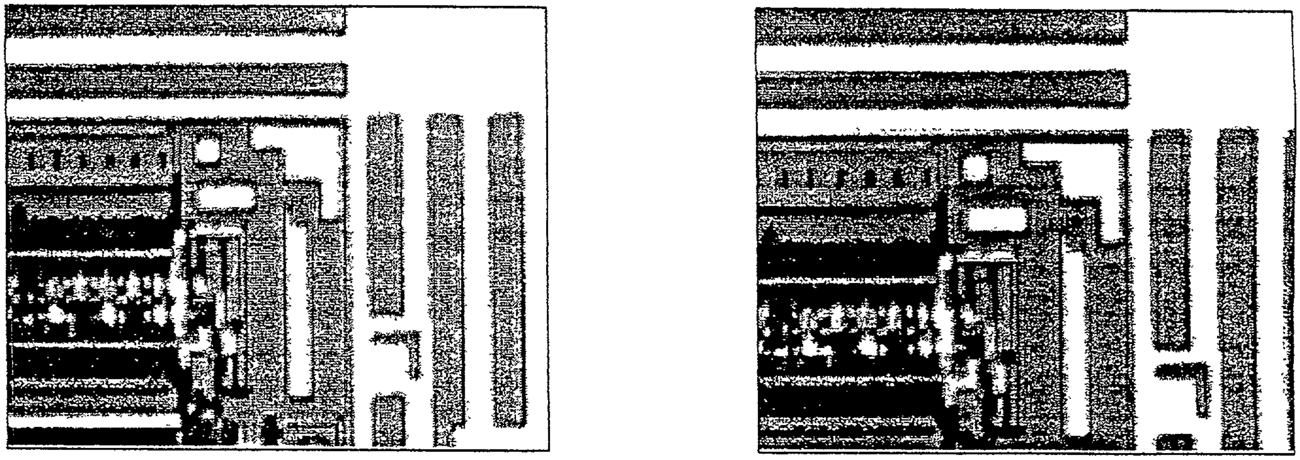

Figure 5. Field-of-view of a semiconductor wafer exhibiting scale changes due to variations in the camera's "Z "positioning.

Vision Challenge 5: Pattern recognition must handle partial obliteration or missing features.

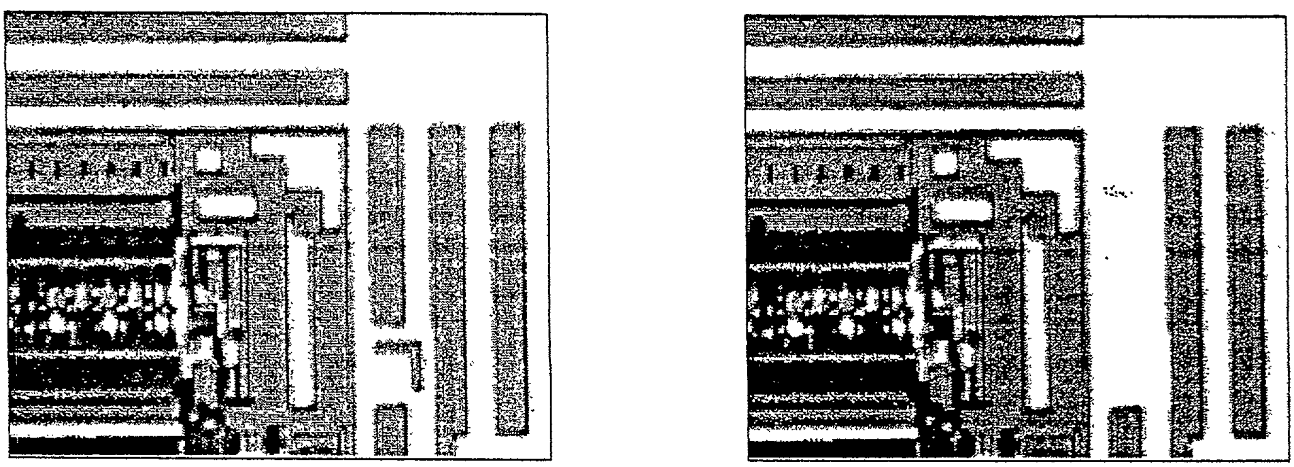

Figure 6. Field-of-view of a semiconductor wafer exhibiting missing features due to the application of a corrective laser trimming process.

Traditional Machine Vision Approach

Traditional normalized grayscale correlation tools are adequate for locating patterns under ideal conditions. However, they exhibit low tolerance to image changes in scale, angle, blur, obliteration and contrast variation. Also, correlation score resulting from the pattern recognition process is the sole indicator of confidence. Unfortunately, correlation score is sensitive to degraded images and introduces inaccuracies when images are degraded with contrast changes, lighting gradients, scale, obliteration, rotation, and blur.

So, given this common set of requirements for fine alignment of patterned wafers it can be said that standard normalized grayscale correlation tools are essentially rendered ineffective for such applications. From this arises the need for more adaptable pattern recognition tools that can cope with acceptable changes in appearance due to process variations found in today's manufacturing environments.

State-of-the-Art Machine Vision Approach

In order to effectively solve the fine alignment of patterned wafers application an adaptive pattern locating tool is required. Prerequisite characteristics of this tool include:

- Intelligent scoring process for locating patterns
- Report of % in conformance relative to trained pattern
- Report of angle variance from the trained pattern
- Report of contrast variance from the trained pattern
- Precisely locates patterns despite degraded images
- Training Wizard to take the guesswork out of pattern training for worst-case run-time conditions

The new generation of geometric based pattern recognition algorithm is a good example of an adaptive pattern finding tool. This new technique incorporates a highly innovative method that has proven to be extremely reliable in locating the position and orientation of objects despite highly degraded run-time patterns or images. This new tool locates patterns with precision that is 15 times greater than most commonly used tools (i.e., normalized grayscale correlation), and maintains high precision despite changes in object/pattern size, orientation, shape, focus, contrast, or partial occlusion.

Using proven techniques, the new search engine incorporates a geometrical assisted pattern locating tool which automatically adapts to process variations most often encountered during the manufacturing process, while still maintaining up to 1/60th sub-pixel accuracy and repeatability.

To take the guesswork out of the pattern training process, the new search tool includes a Training Wizard which uses proven artificial intelligence techniques to optimize run-time parameters thereby eliminating the need for the traditional "trial and error" efforts mandated by other commercial pattern locating tools. This enables the user to train the vision system on virtually any location or pattern while the Training Wizard automatically computes optimal run-time parameters that enables the search tool to cope with normal process variations that may be encountered at run-time.

SUMMARY

A key element to success in both of the above applications was a pattern recognition tool that is able to locate objects or patterns despite a wide variety of visual variations that occur during run-time. Imaging Technology's new sub-pixel engine is able to accurately locate such patterns to <u>1/60th pixel accuracy</u>, even when run-time images or patterns exhibit missing features, noise, and random artifacts. In addition, non-linear lighting gradients, including contrast reversal and specular reflections, as well as certain variations in angle and scale are adeptly handled by this new search tool. In situations where only minimal pattern features are visible, This new search engine is still able to precisely locate patterns or fiducials. This robust performance eliminates the need for automation engineers to install expensive handling equipment or costly lighting apparatus.

One of the most important and potentially time-consuming aspects of setting up a vision system is training the pattern recognition tool to work under a variety of process conditions. To eliminate this tedium, this search engine includes an intelligent Training Wizard, which takes hours, if not days of laborious guesswork out of the pattern training process. The Wizard is able to train on any pattern, providing the user with an extremely straightforward "show and go" process. In operation, the Training Wizard creates test suites of templates and images, while evaluating and optimizing search parameters to provide the best possible pattern locating performance at run-time. No other commercially available vision alignment tool on the market provides such an advanced pattern training utility.

This new search technique raises the bar for other vision alignment software tools, providing average search speeds that are up to <u>5 times faster</u> and <u>15 times more accurate</u> than competing products. This new level of performance is made possible through industry-proven techniques that were once time-prohibitive for time-critical automated vision applications. Now, with the advent of 450 MHz Pentiums® and MMX® acceleration, these proven techniques are, at last, viable for use in high-speed vision alignment.